2-5 Frequency Calibration

SAITO Haruo, IWAMA Tsukasa, TSUCHIYA Shigeru, and KOYAMA Yasuhiro

The Japan Standard Time (JST) and the Coordinated Universal Time (UTC(NICT)), which are constructed by National Institute of Information and Communications Technology (NICT), and these source is a national standard of the frequency in Japan. One of the biggest missions for NICT is to distribute frequency standard to the industrial world.

With this paper, we report on the frequency calibration service as one of the distribution methods. In addition, we make a report of new calibration services. We are now engaged in introducing an optical frequency calibration system, a time difference calibration system and a remote frequency calibration system using the JJY as new services.

Keywords

Frequency standard, ISO/IEC 17025, Uncertainty, ASNITE accreditation service, Jcss calibration service

1 Introduction

1.1 Frequency standard calibration at NICT

The calibration by NICT began on December 14, 1984, when the public notice on the commissioned performance testing and calibration of radio facility equipment in compliance with Article 5 Item 22-12 of the Act for Establishment of the Ministry of Posts and Telecommunications (currently Article 14-5 of the Act on the National Institute of Information and Communications Technology, Independent Administrative Agency) was revised.

Thereafter, in accordance with the revision of Article 102-18 of the Radio Law, NICT and other organizations have been obliged to perform the calibrations on measurement instruments for inspecting radio facilities that accredited inspection providers (currently attested private inspectors) use since October 1997. In addition, NICT, as a designated calibration organization accredited by the Minister of Economy, Trade and Industry in accordance with the Measurement Law, has carried out calibration on frequency standards since April 2003[1][2].

The calibration items offered by NICT for frequency standards as of September 2010 are shown in Table 1, and measurement for each item is carried out at 1MHz, 5MHz and 10MHz frequencies. In the table, the “commissioned calibration” is measurement in compliance with Article 14-5 of the Act on the National Institute of Information and Communications Technology, Independent Administrative Agency; “calibration in compliance with the Radio Law” is measurement of measurement

Table 1 *Calibration items offered by NICT*

	Calibration in compliance with the Radio Law	Calibration in compliance with the Measurement Law	Commissioned calibration
Frequency Deviation	Carried-in Calibration	Carried-in & Remote Calibration	Carried-in & Remote Calibration
Short-term stability	—	—	Carried-in Calibration
Reproducibility	—	—	Carried-in Calibration

—: N/A

instruments used by attested private inspectors in accordance with Article 102-18 of the Radio Law; and “calibration in compliance with the Measurement Law” is measurement carried out as a designated calibration organization in accordance with Article 135 of the Measurement Law. In addition, 2 types of measurement methods are provided[1]; measurement carried out at the designated location within NICT (carry-in calibration) and measurement carried out via satellite without moving the frequency standards to NICT (remote calibration).

Figure 1 shows the annual number of measurements from fiscal 1997, when NICT was obliged to carry out calibration in compliance with the Radio Law (actual calibration commenced in fiscal 1998) until fiscal 2009. Since around 2004, the number of calibrations in compliance with the Measurement Law has increased, while the number of calibrations in compliance with the Radio Law has decreased (there was a temporary increase in fiscal 2005). This is because in accordance with the revision of the Radio Law in June 2003, the calibration of measurement instruments used by attested private inspectors no longer had to be carried out by only NICT or another designated calibration organization (Telecom Engineering Center). Since calibration in compliance with the Measurement Law was also approved, former users of calibration in compliance with the Radio Law also became able to use calibration in compliance with the Measurement Law.

1.2 International system of units (SI) traceability

Domestic national standards for frequencies and time did not exist until 2003 due to the historical circumstances (legal inadequacies), despite requests from industry. To put it another way, in spite of having participated in the Metre Convention, frequency standards and time standards did not conform to the International System of Units (SI) in Japan until then.

At the Standards Board of the Measurement Administration Council in December 2002, the verdict was reached that frequency standards of the National Institute of Advanced Industrial Science and Technology and NICT would be designated as the national standards for frequency (Specified Standard in the Measurement Law), and finally a standard provision system traceable to the International System of Units (SI) was created in Japan. In addition, in accordance with this verdict, NICT was designated as a designated calibration organization by the Minister of Economy, Trade and Industry as of April 1, 2003[2].

Even before this, from fiscal 2000, NICT had been working on acquisition of General re-

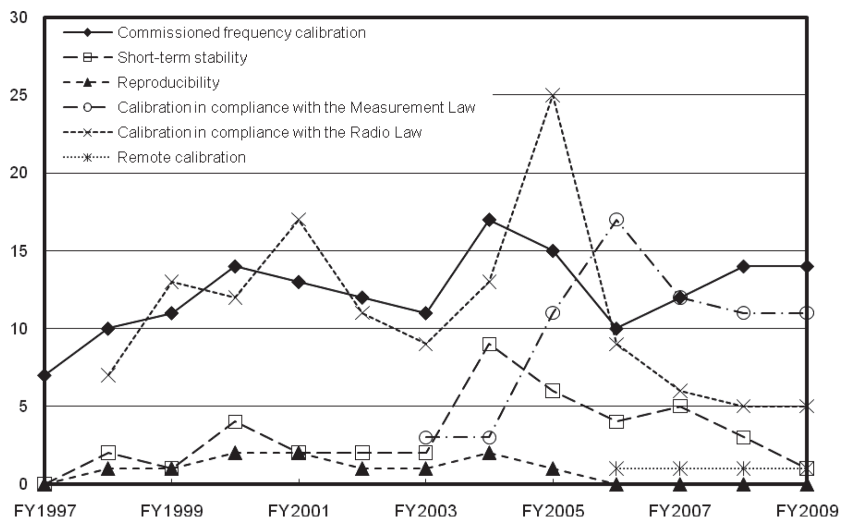

Fig.1 *Transition of the annual number of calibration*

quirements for the competence of testing and calibration laboratories accreditation (ISO/IEC 17025; JIS Q 17025), and received ISO/IEC17025 certification in March 2001 from the Ministry of Economy, Trade Industry National Institute of Technology and Evaluation (the current National Institute of Technology and Evaluation, Incorporated Administrative Agency hereinafter "NITE") (as official ISO/IEC 17025 certification, NICT obtained ASNITE accreditation in January 2003 from NITE), and became able to issue global MRA calibration certificates. Because the measurement calibration certificates issued as a designated calibration organization in accordance with the Measurement Law are directly used in the marketing of domestic specified secondary standards, they are not Global MRA certificates (however, calibration certificates measured by domestic specified secondary standards (JSCC calibration service certificates) are taken as Global MRA certificates)[1][3].

This paper reports on the details and precision of frequency calibration systems operated by NICT and the introduction of new calibration works including optical frequencies.

2 Frequency calibration system

As noted above, in NICT's frequency calibration work, Device Under Test (hereinafter, referred to as "DUT") is carried out through 2 systems, a carry-in calibration system and a remote calibration system. Figure 2 shows the layout of the inside of the calibration room (test room and antechamber). The interior of the test room is electromagnetically shielded and the temperature is maintained within a range of 23°C±2°C and humidity is 50%±10%. The antechamber is not electromagnetically shielded but the temperature is maintained within a range of 23°C±5°C and humidity 50%±10%. The counters for the carry-in calibration system are installed in the test room and the control PCs for them and the remote calibration system are settled in the antechamber. Figure 3 shows the counters and control PCs and Fig. 4 shows the remote calibration systems (base station).

2.1 Carry-in calibration system

The current calibration system was newly

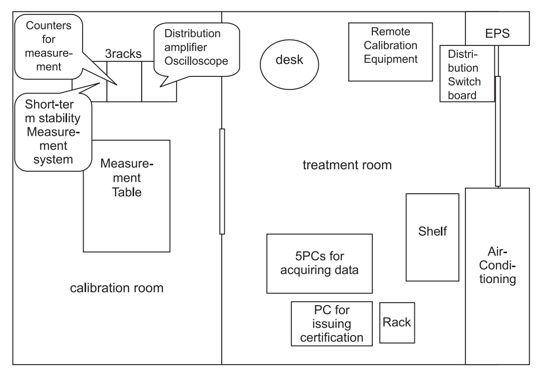

Fig.2 *An arrangement plan in the calibration room*

Fig.3 *Counters for measurement (left) and PCs for control (right)*

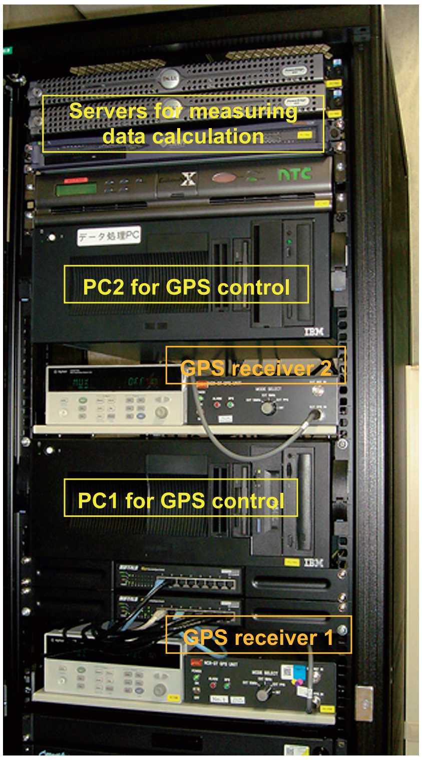

Fig.4 *Remote calibration system for the base station*

installed in the calibration room in Network Jikoku Ninsho building (building 2) established in fiscal 2005, and underwent accreditation screening on the occasion of the ASNITE accreditation periodic screening conducted by NITE in February 2006, and started formal operation after being certified. Measurements of short-term stability and reproducibility are, however, beyond the scope of ASNITE accreditation.

(1) Frequency deviation measurement

The system structure of the frequency deviation measurement is nearly the same as the former system[1], and 4 counters are used for simultaneous measurement of up to 4 DUTs. In the previous system, 4 counters were controlled by one control PC; however, in the current system each counter is connected to each control PC in an attempt to improve measurement simultaneity.

There are 2 measurement methods, a direct frequency measurement method used when frequency deviation is larger than 1×10^{-8}, and a time interval measurement method used when it is smaller than that. Both measurements are carried out for 24 hours. In addition, at first, running DUT warm-up operation for 24 hours and a preliminary measurement are conducted for system checks, then the measurement method is determined, and finally a main measurement is carried out. It takes about two days to complete a measurement.

I Preliminary measurement

For preliminary measurement, the time interval counters (Stanford Research Systems SR620, hereinafter referred to simply as “counters”) are used, and 10s-gate-time measurements are carried out 100 times as same as for the direct frequency measurement method, and then either the direct frequency measurement method or time interval measurement method will be chosen to be adopted based on the average value of the measurements.

II Direct frequency measurement method

10s-gate-time measurement is performed for 24 hours using the counter’s direct frequency measurement mode and frequency deviation and measurement uncertainty of the DUT are calculated from 8640 data. The basic frequency of the counter is synchronized to the reference frequency.

III Time interval counter measurement method

Using the counter’s time interval measurement mode, the trigger level is set at 0V, the DUT signal is connected to the counter’s A input and the standard frequency of 10MHz signal is connected to the B input, and the time (phase) difference is measured every 1 second. Measurement is carried out for 24 hours, and the obtained 86400 data are split into 60 items and each of them consists of consecutive 1440 (24 minutes) data, and then statistical calculation is carried out to find the frequency deviation and uncertainty.

In the former system, the measurement methods of the commissioned calibration and calibration in compliance with the Radio Law were different from the calibration in compliance with the Measurement Law; however, in the current system both are standardized as the methods mentioned above[1].

(2) Short term stability measurement

Measurement is carried out with measurement equipment based on the DMTD (Dual Mixer Time Difference) method and exclusive counters[4]. In the former system, the measurement was performed via the same method using measurement equipment and counters; however, the measurement equipment has been updated in the current system. The DMTD method is a method for carrying out high precision comparison in which a DUT output signal, whose frequency is nearly identical to a standard frequency. The DUT output signal and the standard signal shall be beaten down to the measured frequency of 1kHz by using a signal source, whose frequency is 1kHz lower than their outputting frequency, and 2 mixers, and then the phase difference is measured using counters. A frequency synthesizer (HP8662 A) synchronized to the standard frequency is used for the beat-down signal source.

Measurement is carried out using the counter's time interval measurement mode at 1-second intervals for 2 hours, and frequency stability at 1s, 3s, 10s, and 100s is calculated respectively from the measured 7200 data.

In addition, since frequency system checks and 24-hour DUT warm-up operation are required in the same manner as deviation measurement before measurement, it will take 26 hours or more for a measurement procedure.

(3) Reproducibility measurement

Measurement is carried out using the same counters and control PCs as for the measurement system of short-term stability. The DUT is restarted after cutting the power supply for 24 hours, and the frequency deviations after 1 hour, 4 hours, and 24 hours are compared with the frequency deviation before turning off.

After performing the 24-hour DUT warm-up operation and system checks, frequency deviation is measured for 1 hour, and then the frequency deviation before turning off is calculated. After the DUT is stopped and restarted after 24 hours, the frequency deviations after 1 hour, 4 hours, and 24 hours have been measured for one hour respectively (actual measurements are for 1-hour from 30 min, 3 hr and 30 min, and from 23 hr and 30 min after the restart respectively), then each measured deviation is compared with the deviation before being stopped, and the measurement values for 3 points are calculated. For this reason, 3 or more days are required for the measurement.

2.2 Remote calibration system

NICT developed a remote frequency calibration system from 2001 and started to operate actual measurement from May 2005. The system underwent accreditation screening on the same occasion of the ASNITE accreditation periodic screening for the carry-in calibration system conducted by NITE in February 2006, and then ASNITE accreditation was given in May. In addition, calibration in compliance with the Measurement Law has also been implemented since April of 2007.

Remote frequency calibration is performed using the GPS-common-view method[5] which uses GPS satellites. As a result, this has avoided problems with carry-in calibration such as (1) impossibility to use frequency standards during measurement, (2) impossibility to perform carry-in measurement at remote locations, and (3) possibility of malfunctioning of DUT during transport.

Figure 4 shows a photo of the base station for remote calibration system. 2 systems, including a backup (GPS receiver 2 in Fig. 4), are used for the GPS receivers.

DUT measurement data is encrypted and stored on the internal data servers at NICT through internet, and then the frequency deviation and frequency stability (averaging time of 1 and 5 days) for that month are calculated from 1 month's data, and a calibration certificate is issued every month. In addition, the workers who work within the client's site provided by the client are referred to as support staffs and carry out measurement as NICT calibration personnel when implementing the work concerned.

Because highly precise measurement[1] using dual frequency multichannel GPS receivers, which was the original purpose of development, does not make big difference from measurement using single frequency multichannel GPS receivers, and because it is considered to be difficult for users to use dual ones due to the high cost, only the single frequency multichannel GPS receivers, which NICT requested Japan Radio Co., Ltd. to develop, are used at the base station in the current system.

2.3 Measurement uncertainty and maximum measurement capacity

"Measurement uncertainty" is defined in the *International vocabulary of basic and general terms in metrology* as "parameter that characterizes the dispersion of the quantity values that are being attributed to a measurand," and the "best measurement capability" of measurement systems is defined in Article 90 Item 2-2 of the Measurement Law enforcement regulations (1993 Ministry of International Trade and Industry Ordinance 69) as follows:

"The minimum uncertainty of measurement is established by the International Committee for Weights and Measures. The minimum uncertainty of measurement which can be achieved in the recorded range when implementing calibration of measurement instruments used to realize a single unit or 1 or more values of a measurement amount, or when implementing the calibration of measurement instruments used to measure the relevant amount".

In short, the uncertainty recorded by International Bureau of Weights and Measures (BIPM) is the same as the best measurement capability of the measurement system and therefore indicates the best performance of the measurement system.

The uncertainty of carry-in calibration and remote calibration measurements by NICT is recorded in the Calibration and Measurement Capabilities of International Bureau of Weights and Measures, and the current values for each are as follows: carry-in time interval measurement method 5×10^{-14}, carry-in direct frequency measurement method 2.5×10^{-12}, and remote calibration 5×10^{-13}. It is necessary to maintain the uncertainty value of each measurement amount to be traceable to the International System of Units (SI), and traceability from the definition of the second is required in the time/frequency domain.

3 New calibration services

3.1 Time scale difference calibration

As mentioned in Chapter **1**, at present, time scale difference calibration and time interval calibration are not carried out in Japan. This is a result of historical circumstances until now, and because the determination of the (central) standard time is legally the jurisdiction under the National Astronomical Observatory of Japan (National University Corporation Act enforcement regulations), and the distribution of standard time is under NICT (Act on the National Institute of Information and Communications Technology, Independent Administrative Agency); however, what national standards shall be provided in what way is not stipulated.

It was reported at the Technical Committee Time Subcommittee of JCSS in January 2010 that the National Institute of Advanced Industrial Science and Technology would start time scale difference calibration and NICT has also begun examinations aimed towards the implementation of time scale difference calibration.

Existing measurement systems of carry-in and remote measurement systems can be used with very little modification, and so testing work is planned to start as early as from the fall of 2010 and to undergo accreditation screening at the time of the ASNITE accreditation periodic screening (including peer review) for frequency calibration systems in February 2011.

3.2 Optical frequency calibration

The construction of an optical frequency calibration system was commenced in fiscal 2010.

The basis of this system is to extend the microwave standard frequency into the optical frequency band using an optical comb, and

NICT plans to carry out measurement of the optical communication frequency band. At present (September 2010), NICT prepares for the calibration system and plans to perform test operation in the latter half of fiscal 2010.

3.3 Frequency remote calibration using LF standard-time and frequency-signal transmission (JJY)[6][7]

Due to expectations from industry for an inexpensive and easy to use frequency standard and because use of the LF standard-time and frequency-signal transmission (JJY) in the standard frequency field has not progressed, development of a remote frequency calibration system using JJY started in 2008.

The main themes of development are the development of a JJY receiver for calibration systems and the establishment of calibration methods; a prototype receiver was created in fiscal 2008 and an improved version in fiscal 2009, and operation verification is currently ongoing. For the calibration method, it is planned that the JJY transmission wave phase is temporarily modified, and the phase change amount of signals received by JJY receiver and signal change amount of transmission at this time are compared, and then the frequency deviation of output signal of a JJY receiver, for which capability has been verified beforehand, is evaluated, and after confirming the proper operation of the JJY receiver, the DUT frequency deviation is measured based on that output.

During fiscal 2010 it is planned to verify the operation of the improved JJY receiver, and to carry out verification of the radio propagation conditions and calibration methods at each area in Japan, then to create the JJY receiver for the final frequency calibration system, and to carry out work for consigned calibration during fiscal 2011.

4 Conclusion

In this paper, we have reported the details of NICT's frequency calibration service and the current status as well as the progress of the introduction of new calibration services.

Frequency calibration service by NICT conforms to the requirements of ISO/IEC 17025; JISQ 17025, and all the necessary documents have been prepared and operation is carried out in accordance with those regulations. We also plan to successively obtain ISO certification for the new calibration services introduced in Chapter **3**, and provide high quality standards in the time/frequency domain to meet the needs of industry both within Japan and overseas.

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SAITO Haruo

Expert, Space-Time Standards Group, New Generation Network Research Center

Time and Frequency Measurement

IWAMA Tsukasa, *Ph.D.*

Research Manager, Space-Time Standards Group, New Generation Network Research Center

Secure Time Stamping, Time Dissemination & Synchronization

TSUCHIYA Shigeru

Senior Researcher, Space-Time Standards Group, New Generation Network Research Center

Time and Frequency Standard, Radio Wave Propagation

KOYAMA Yasuhiro, *Ph.D.*

Group Leader, Space-Time Standards Group, New Generation Network Research Center

Space Geodesy, Radio Science